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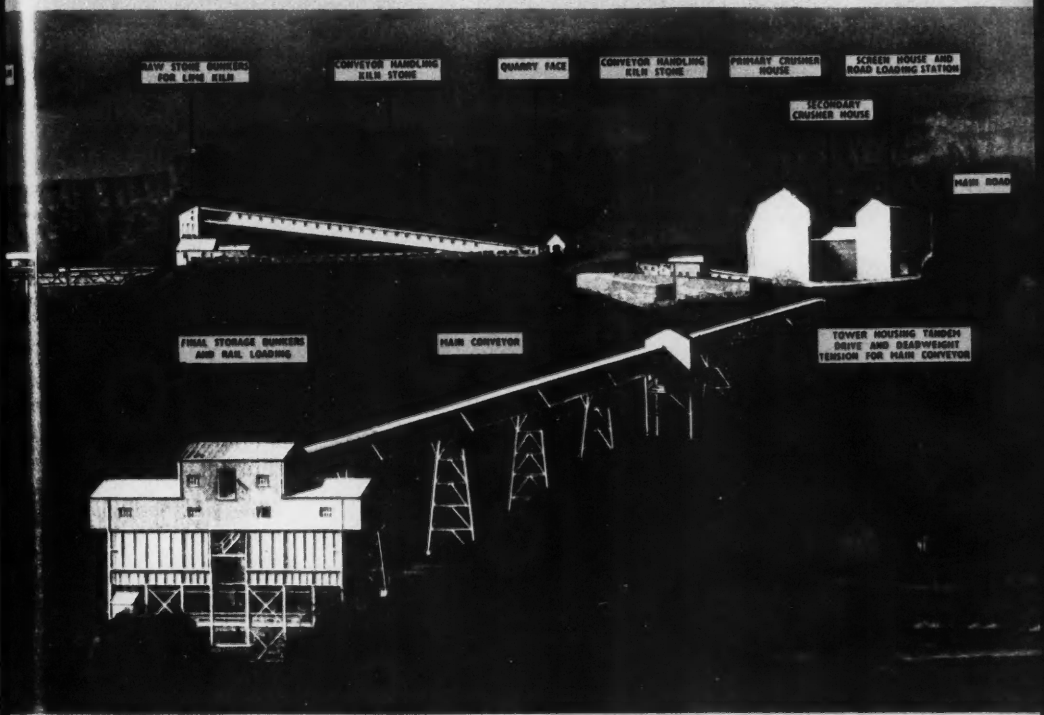
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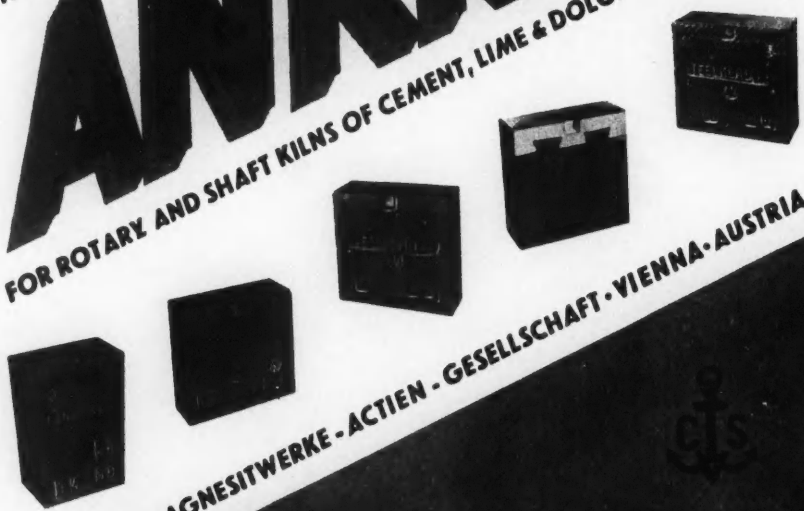

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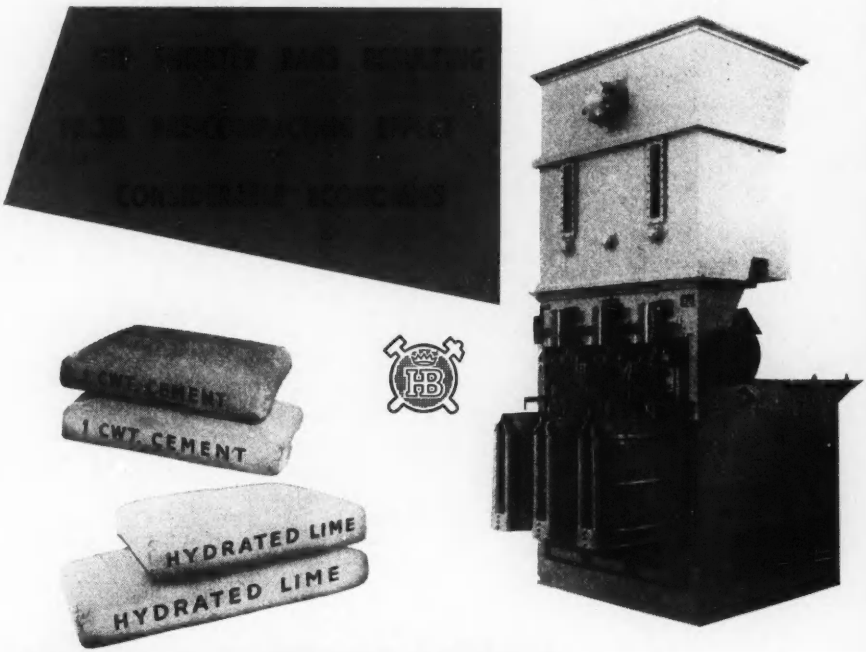

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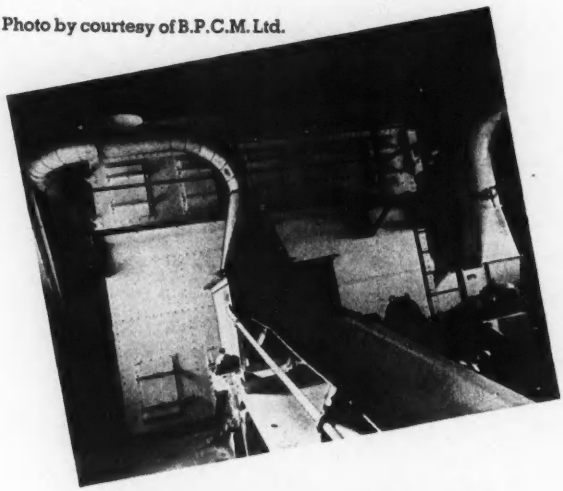

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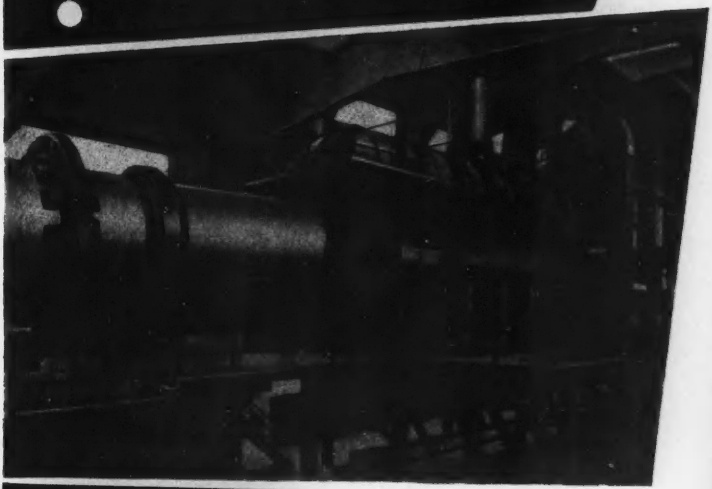

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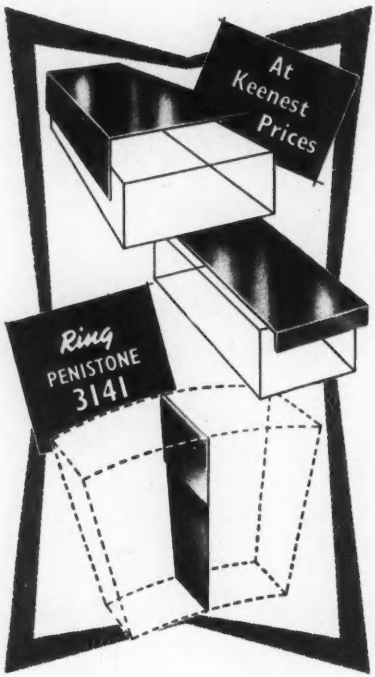

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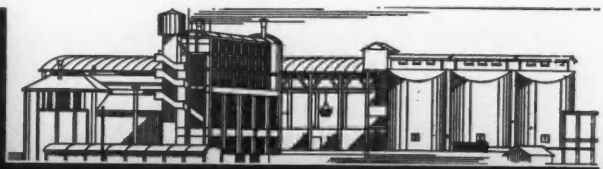

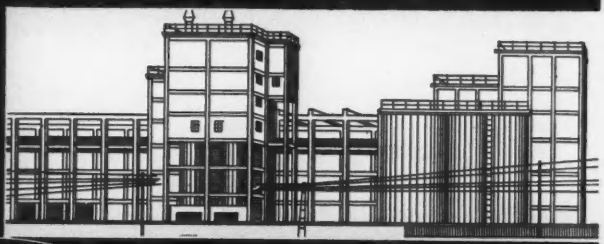

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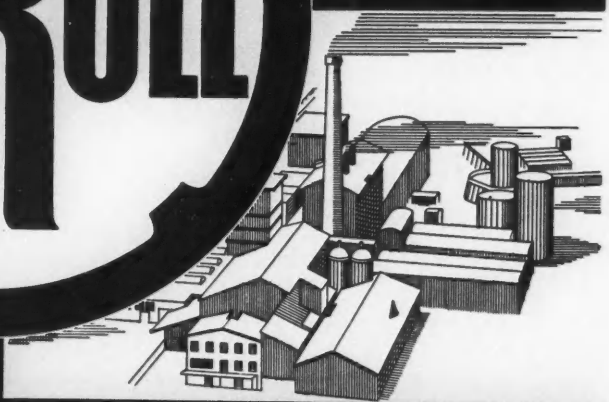

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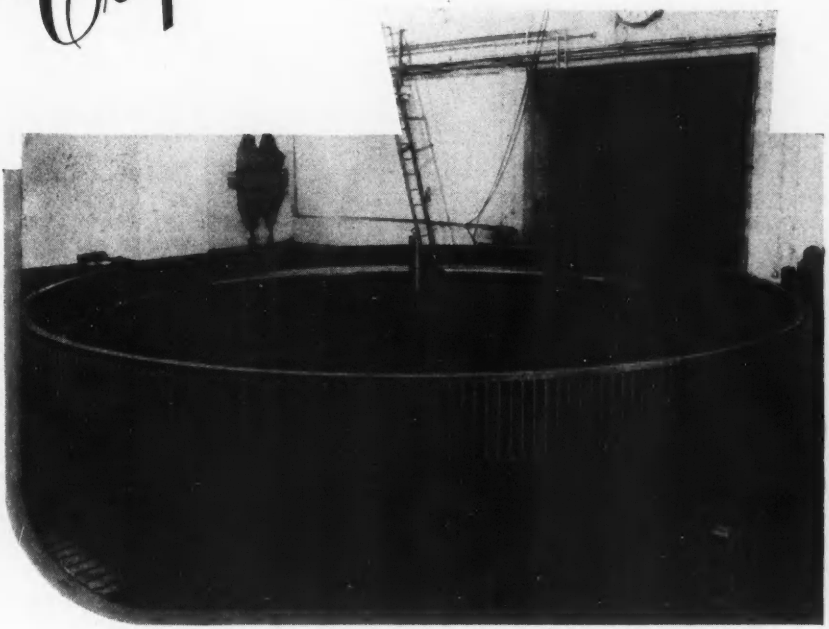

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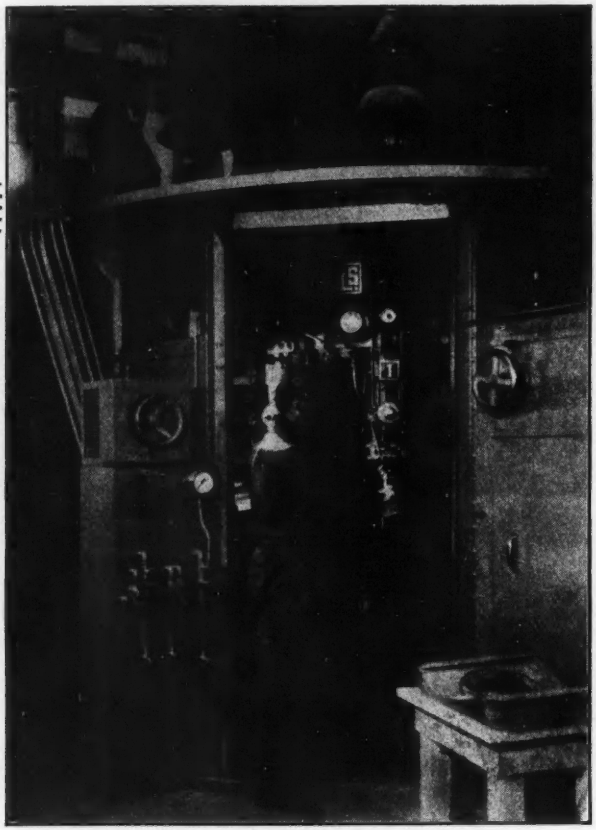

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VOLUME XXXI. NUMBER 6. NOVEMBER, 1958

Tests on Portland Cement Clinker with High Content of MgO.

THE properties of Portland cement are determined by its mineralogical composition and physical structure, both of which depend on the rate of the cooling of the clinker. If the clinker is cooled rapidly the cooling period is then too short to allow the crystallisation processes to be completed, and the resulting structure is of a glassy nature. In this state, the minerals of the clinker consist of crystals that are much smaller in size than similar crystals formed during normal cooling, and their proportion in the clinker is also different.

The rate of cooling is particularly important if appreciable amounts of MgO are present. A rapidly-cooled clinker contains less periclase and a higher proportion of magnesia in the form of solidified liquid phase, which remains to a great extent in the glassy state. Furthermore, the dimensions of the periclase crystals are considerably smaller tnan those in clinker cooled normally.

For this reason the expansion of high-magnesia cement in autoclave tests is usually much less in the case of cements produced from rapidly-cooled clinkers. However, the expansion of high-magnesia cements after longer curing, caused by hydration of periclase, can be kept small and uniform, thus avoiding cracking in concrete due to expansion.

The problem of producing high-magnesia Portland cement with volume-stability characteristics similar to those of ordinary Portland cement is important, since at present many deposits of raw materials are considered unsuitable for the manufacture of cement solely because of a high content of MgO. Investigations undertaken by S. M. Rojak and V. V. Myshlaeva on the water-quenching of Portland cement clinkers with a high-magnesia content, and reported in " Tsement " for June 1957, are therefore of interest, and the results are abstracted in the following.

TABLE 1.—MINERALOGICAL COMPOSITIONS

Clinker No.	Type of cooling	Calculated mineralogical composition (per cent.)				MgO (per cent.)	Free CaO (per cent.)	Lime saturation (per cent.)	Silica modulus	Alumina modulus
		C_3S	C_2S	C_3A	C_4AF					
		Clinkers burnt in experimental rotary kiln								
5-5r	Normal and rapid	31	31	9·1	18·3	10·2	None	0·81	1·48	1·18
6-6r	Do.	28	32	6·7	18·9	13·0	None	0·80	1·53	1·03
		Commercial clinkers								
P-5	Normal	47	23	7·8	13·9	6·6	0·74	0·87	1·95	1·28
P-5r	Rapid	50	21	7·8	13·9	6·6	0·12	0·88	1·95	1·28
P-6	Normal	54	15	6·8	13·7	7·8	0·86	0·91	1·98	1·20
P-6r	Rapid	57	13	6·8	13·7	7·2	0·14	0·92	1·98	1·20
P-7	Normal	42	26	9·3	13·9	7·8	1·41	0·85	1·79	1·41
P-7r	Rapid	44	24	9·3	13·9	7·0	0·12	0·86	1·79	1·41

TABLE 2.—RESULTS OF PETROGRAPHIC INVESTIGATION OF CLINKER

Clinker No.	Type of cooling	C_3S			C_2S			Interstitial matter (per cent.)	Free lime crystals of phenolates	MgO (per cent.)	Periclase		
		Amount (per cent.)	Crystal size (μ)		Amount (per cent.)	Crystal size (μ)					Amount (per cent.)	Crystal size (μ)	
			from	to		from	to					from	to
5	Normal	30	20	40	35	20	30	35	None	10·2	9·0	5	15
5r	Rapid	35	3	25	30	3	20	35	None	10·2	8·0	2	8
6	Normal	40	15	30	30	15	25	30	None	13·0	10·0	5	15
6r	Rapid	40	15	25	25	10	40	35	None	13·0	10·0	2	12
P-5	Normal	45	25–30	100	25	15	55	30	2–3	6·6	5·6	5	24
P-5r	Rapid	50	10	70	25	10	40	25	1–2	6·6	4·5	5	20
P-6	Normal	55	25–60	80–100					Considerable	7·8	7·2	5	32
P-6r	Rapid	55	20–45	70	15	10	40	30	None	7·2	3·0	4	12
P-7	Normal	45	25–45	150	30	20	50	25	Considerable	7·8	7·0	5	32
P-7r	Rapid	45	20–40	100	30	20	50	25	1	7·0	6·0	4	24

TABLE 3—STRENGTHS OF CEMENTS MADE WITH RAPIDLY-QUENCHED AND SLOWLY-COOLED CLINKERS

Clinker No.	Type of cooling	MgO content (per cent.)	Grinding fineness (residue on sieves) per cent.		Specific surface (sq. cm./g.)	Strength, lb. per sq. in.					
						Compression			Tension		
			021	0085		3 days	7 days	28 days	5 days	7 days	28 days
5	Normal	10·2	0·4	6·0	3410	3760	4410	5790	302	313	339
5r	Rapid	10·2	0·3	5·3	3570	3440	3770	6170	344	376	380
6	Normal	13·0	0·4	6·6	3450	2490	3760	5600	252	260	336
6r	Rapid	13·0	0·3	5·6	3190	—	—	7350	—	—	427

An experimental kiln 23 ft. long was used for the tests. Samples of clinker from the end of the burning zone (at a temperature of about 1350 deg. C.) were quenched in water and tested; samples were also taken and cooled slowly for the purpose of comparison. The experimental work was supplemented by tests on clinker, made under works conditions, from the cooling zone of a long rotary kiln (at 1350 deg. C.) and also quenched in water.

In *Table* 1 are given the calculated mineralogical compositions of the test clinkers, and the results of petrographic analyses are shown in *Table* 2. From this table it is clear that the amounts of periclase in the rapidly-quenched clinkers are lower by between 1 and 4 per cent. than in the slowly-cooled clinkers. It is also clear that rapid cooling produces periclase with a very much finer crystalline structure.

The clinkers were then ground in a laboratory ball-mill, with an addition of 4 per cent. of gypsum hemihydrate (about 2 per cent. of SO_3) until the residue on a 0085 sieve was between 5 and 7 per cent. The specific surface area of the laboratory clinkers (Nos. 5 and 6) was 3190 to 3520 sq. cm. per gramme and that of the works clinkers (Nos. P5, P6, and P7) from 2670 to 2940 sq. cm. per gramme.

All the cements passed the volume-stability tests in boiling water and in storage in water for 28 days. During these tests, however, the periclase present remained unhydrated, and use was therefore made of autoclave curing (at 20 atmospheres for three hours) as a criterion of quality, since it is only then that all the periclase is hydrated. Earlier investigations have shown that the strength of high-magnesia Portland cement cured for one year or more can be forecast to a known degree of accuracy from its behaviour during autoclave curing at a pressure of 20 atmospheres. As a rule, all cements failing in the autoclave test have low strengths at later periods, or disintegrate as a result of delayed hydration of the periclase. On the other hand, cements passing the autoclave test were found to increase in strength steadily for periods of up to five years.

The volume-stability of the cement was tested using cylindrical specimens, and the linear expansion was measured on prisms of cement paste. After curing in a moist atmosphere for 24 hours, the cylinders were boiled in water for four hours in order to hydrate the free lime, and were then subjected to autoclave curing at 8 atmospheres for four hours, 14 atmospheres for two hours and 20 atmospheres for three hours. The prisms were moist-cured for 24 hours; needles were then inserted in the ends, and the linear expansion was measured after curing for a further 24 hours. The values so obtained served as the starting point for the subsequent tests.

Three of the prisms were cured in cold water and three were boiled in water for four hours and the changes in lengths noted. The specimens were then autoclaved at 8, 14, and 20 atmospheres; after each test the change of volume was measured and expressed as a percentage of the initial volume. The linear expansions are given in *Table* 4, from which it can be concluded that cements obtained from rapidly-cooled clinkers usually perform well in the autoclave test even at 20 atmospheres and generally have less expansion after autoclave curing. Cement

TABLE 4.—LINEAR EXPANSION OF CEMENTS PRODUCED WITH CLINKERS COOLED AT VARIOUS RATES.

Cement No.	Type of cooling	Contents per cent.			Autoclave tests		Prism expansion (per cent.)										
		Free lime	MgO	Peri-clase	14 atm.	20 atm.	Boiling for 4 hours	Autoclave tests (pressures)			Water curing						
								8 atm.	14 atm.	20 atm.	14 days	28 days	3 mth	6 mth	1 year	2 years	3 years	4 years
5	Usual	None	10·2	9·0	Passed	Passed	0·10	—	0·20	0·38	0·01	0·03	0·10	0·13	0·18	0·36	0·40	0·60
5p	Rapid	None	10·2	8·0	Passed	Passed	0·08	—	0·09	0·21	0·01	0·02	0·10	0·12	0·13	0·30	0·38	0·53
6	Usual	None	13·0	10·0	Passed	Passed	0·15	—	0·17	Cracks	0·07	0·10	0·22	0·30	0·44	Cracks	Destroyed in 2½ years	
6p	Rapid	None	13·0	10·0	Passed	Passed	0·10	—	0·23	Deformed	0·04	0·08	0·15	0·25	0·33	0·63	0·86	0·98 (Cracks)
P-5	Usual	0·74	6·6	5·6	Passed	Failed	0·06	0·14	0·36	Destroyed	0·05	0·10	0·14	0·18	0·22	0·23	—	—
P-5p	Rapid	0·12	6·6	4·5	Passed	Passed	0·06	0·16	0·25	0·61	0·01	0·02	0·06	0·10	0·13	0·17	—	—
P-6	Usual	0·86	7·8	7·2	Passed	Failed	0·12	0·19	0·38	Destroyed	0·06	0·12	0·16	0·23	0·25	0·30	—	—
P-6r	Rapid	0·14	7·2	3·0	Passed	Passed	0·05	0·14	0·21	0·47	0·02	0·03	0·08	0·12	0·14	0·19	—	—
P-7	Usual	1·41	7·8	7·0	Failed	Failed	0·09	0·28	Destroyed	Destroyed	0·07	0·13	0·16	0·23	0·25	0·32	—	—
P-7r	Rapid	0·12	7·0	6·0	Failed	Failed	0·08	0·38	2·28 (Cracks)	Destroyed	0·02	0·03	0·08	0·11	0·13	0·17	—	—

No. P7 was an exception in this respect, presumably because rapid quenching of the corresponding clinker reduced the periclase by only 1 per cent. This appears to be due to a high content of calcium aluminate. Clinker P7 had 9·3 per cent. of tricalcium aluminate, compared with 6·8 and 7·8 per cent. in clinkers P5 and P6 respectively. *Table* 3 relates to the strengths of cements made with clinkers produced under works conditions with and without rapid cooling. They show that the quenching of such clinker has no definite effect on the strength of the cement. For example, there was a reduction in the compressive strengths at three and seven days, but the 28-days' strength was slightly higher than the average value obtained with the usual method of cooling clinker. In tensile tests much higher values were obtained also at three and seven days.

On the basis of these results it is concluded that the water quenching of high-magnesia clinker has a favourable effect on its structure (reducing the amount of periclase and the size of the crystals) and on the properties of cement by diminishing the autoclave expansion, which is regarded as a basic criterion of quality. The tensile strength is also slightly improved. This is of considerable importance, as normal Portland cement with a high content of magnesia produced from slowly-cooled clinker has a rather low tensile strength.

A Continental Cement Transporter.

A transporter for loose cement which is now being made in East Germany is described in a recent number of "Materialy Budowlane." The transporter (*Fig.* 1) has three removable containers mounted on a trailer. The containers are filled at the cement factory and pressurised by means of a compressor incorporated in the trailer. When delivered, they are removed from the trailer and stored until required, thus avoiding the need for silos.

Fig. 1.

Automatic Control of the Density of Slurry.

SOME details of the equipment installed at the works of the Permanente Cement Company, at Oakland, California, U.S.A., for the automatic control of the density of slurry is given in " Pit and Quarry " for July 1958. The density-gauge was supplied by the Bendix Aviation Corporation and the control instruments by the Minneapolis-Honeywill Brown Corporation. It is stated that the system maintains the water content of the slurry at any desired percentage at all times. Measurement is made through nuclear-energy absorption, with pneumatic control. The density is read through the slurry pipeline without physical contact, affording a continuous record of density without sampling or testing in the laboratory.

The system depends upon the fact that different densities of materials reduce the intensity of nuclear radiation by different amounts; the thicker the material the fewer the rays that pass through it. The density gauge applies nuclear radiation to the pipe carrying the slurry. If the slurry thickens the ion chamber receives fewer rays; immediately the apparatus adjusts the water-valve to allow enough extra water to enter to restore the density.

The source of the nuclear radiation is cesium 137, a metallic salt containing the radio-active isotope of cesium. As cesium 137 slowly disintegrates it emits beta and gamma particles. The beta particles have relatively low energy and are all absorbed in the slurry pipe itself and take no part in measurement or control. The gamma radiation, however, passes through the slurry and both thicknesses of the pipe wall. The gamma rays are detected by the ionisation chamber of the gauge. These rays have the property of ionising a gas in proportion to their strength, and the amount of ionisation determines the amount of electricity that flows between the two electrodes in the chamber. This minute current is amplified and then recorded on the instrument as a measure of density, specific gravity, or percentage of water or solids. Cesium 137 is used as the radio-active source because of its convenient energy level and because of its long period of activity. Means are provided to compensate for the gradual decay of the source, but the error that develops in a year is only 2 per cent.

A layer of lead 2½ in. thick shields all the radiation except that beamed at the stainless-steel ion chamber. The nuclear-source container is said to meet all the requirements for safety of the Atomic Energy Commission. In no case can the slurry become radio-active, and an indicator knob permits the radiation beam to be turned off or on. A single conductor cable is the only connection needed for the sensing element, and the control cabinet may be up to 1,000 ft. from the sensing head.

Control of water content to 35 per cent. plus or minus 0·5 per cent. has been achieved, and control to within 0·25 per cent. is said to be feasible. When desired the scale can be calibrated to control the water content to between 30 and 40 per cent.

Shape and Size of Particles of Slaked Lime.

IN "Zement-Kalk-Gips" for February, 1958, H. v. Zander describes investigations of the shapes and sizes of particles of lime slaked in various ways and examined in the form of pastes. The same initial quicklime was used throughout; this was prepared by burning a natural but pure and finely-crystalline white limestone in a muffle furnace heated by gas to a temperature of 1050 deg. C. Hydration took place under widely differing defined conditions. The particles were examined by means of an electron microscope and the plasticity of the pastes was measured by Mr. Emley's method.

When the quicklime was slaked with excess of water, the resulting paste had a plasticity value of 650; when slaked to form a dry hydrate and then made into a paste, the value for the fresh paste was only 125. Photographs taken with the aid of the electron microscope show clearly that high plasticity is associated with fine particles. The theory that plasticity is associated with a laminar form of the individual particles was not borne out in the case of this particular lime, since in the entire investigation no particle with any marked laminar form was observed. Pastes with rounded particles of 40 μ to 60 μ gave very high values. A paste made with a "dry-slaked" lime had a value of 115 thirty minutes after mixing and of 665 seven days later. Microphotographs showed that the relatively coarse particles of the fresh paste had subdivided into very much finer ones during storage.

It is well known that some hydrated limes produce pastes which increase their plasticity in the course of time and that others produce pastes which have little change in plasticity over long periods. Both these types of hydrate were made by "dry-slaking" in the laboratory; they were called types A and B. In slaking to form type A, some of the heat of reaction was removed by adding ice so that the temperature never exceeded 80 deg. C., and reached this value only a few seconds before falling rapidly. Hydrate of type B was obtained by adding water (60 per cent. by weight of the quicklime, corresponding approximately to the proportions used during manufacture) to the quicklime. The temperature remained steady at 96 deg. C. for several minutes and fell but little during fifteen minutes.

Paste made from type A had a plasticity value of 122 when fresh and 309 after seven days. Microphotographs showed an appreciable reduction in the size of the particles during storage. Paste from type B increased in plasticity value from 106 to only 122 after seven days, with little change in appearance.

The more plastic type A had a residue of 46 per cent. on a sieve with 4900 apertures per square centimetre, while the less plastic type B had a residue of only 3 per cent. This apparent anomaly is explained as follows. Microphotographs show that type A consists of secondary particles built up of small, irregular primary particles; in the dry form these cling together strongly enough to resist disruption by the sieve but fall apart when the system is penetrated by water. Type B consists of larger single crystals.

Hydrates were prepared from the same quicklime by two other methods of

dry-slaking. In the first case slaking took place with the stoichiometric amount of water to which methanol had been added. Evaporation of the methanol removed heat so that the temperature during the process was about 70 deg. C. In the second case moist air was used in the absence of carbon dioxide so that the temperature never exceeded 20 deg. C. In both cases the resulting hydrate was of type A, having high plasticity when made into a paste. The hydrate made in the presence of methanol had the very low weight of 270 grammes per litre and a uniformity of structure not previously observed. It is suggested that this is due to the avoidance of local overheating. Pastes were also prepared by wet-slaking in an analogous manner, but the resulting pastes of hydrates made at 30 deg. C. and at 90 deg. C. showed no significant differences in structure or plasticity.

The photographs of pastes, especially of those stored for a period, reveal a large number of crystals of sizes between 0·03 and 0·1 μ, fewer individual crystals between 1 and 3 μ, and practically no intermediate sizes. In all investigations the diameters of the particles were between 0·02 μ and 50 μ. Assuming that 10 per cent. is between 0·02 and 0·2 μ and the remaining 90 per cent. about 1 μ, the 10 per cent. of fine material would contribute 95 per cent. of the total surface area of the particles. Hence the plasticity is most likely to be affected by reductions of size in the region below 0·2 μ.

The subdivision of the particles of many of the pastes during storage is thought to be associated with the dipole character of water. This view was supported by gauging a hydrate of type A (with a strong tendency to subdivide) with acetone, acetonitrile, methanol, and benzol. No subdivision occurred in any of these during seven days.

A lime having a plasticity value of 650 when slaked with distilled water had a value of only 120 when slaked with a saturated solution of gypsum (the amount of gypsum being 0·66 per cent. of the lime by weight). It is intended in the future to study the effects of slaking at temperatures above 100 deg. C., using an autoclave.

Gypsum and Anhydrite.

A survey of the methods of mining gypsum, its uses, and its occurrence throughout the world, has been published by H.M. Stationery Office under the title " Gypsum and Anhydrite " at a price of 7*s*. 6*d*. The work was prepared by the late Dr. A. W. Groves, and has since been brought up to date. The brochure, of 108 pages, includes an extensive bibliography of the literature of the subject.

New Cement Works in Denmark.

A new cement factory, with a capacity of 125,000 tons a year, has recently been built at Karlstrup, near Copenhagen, at a cost of about 4,000,000 kronen.

Effect of Tobermorite on the Strength of Cement.

THE results of experiments on the effect on the strength of Portland cement of the addition of silica combined with steam-curing are given in a paper by Mr. L. D. Sanders and Mr. W. J. Smothers in the Journal of the American Concrete Institute for August 1957. The purpose of the investigation was to find a high-strength cement for use in the assembly of insulators of the suspension type in high-voltage transmission lines. Previous research by other investigators had shown that the strength of cement was increased by the addition of siliceous materials and steam-curing. For example, a mixture of 60 parts of white Portland cement and 40 parts of quartz sand passing a 200-mesh sieve, allowed to set for twenty-four hours and then cured for twenty hours in steam at a temperature of 170 deg. C., had a tensile strength of 980 lb. per square inch compared with 420 lb. per square inch in the case of neat Portland cement cured in the same way. Another investigator reported compressive strengths of up to 22,000 lb. per square inch in the case of similar mixtures cured in steam.

In the tests now reported ordinary Portland cement (U.S.A. Standard Type 1) was mixed with ground quartz with average particle sizes of 12·7, 18·6, and 20 microns, diatomaceous earth, and a chemically-precipitated silica containing no crystalline material and with an average particle size of 0·022 micron (designated " silica gel "). The specimens containing silica gel had little strength, probably due to the large proportion of water necessary to produce the desired workability with such a fine powder. In the case of the other silicas the strength was generally proportional to the size of the particles, the highest strength being obtained with a particle size of 12·7 microns in a mixture of 65 per cent. cement and 35 per cent. silica. The strength also decreased with a lowering of the temperature of the steam in the autoclave; for example, the strength was about 60 per cent. less when the temperature of the steam was 126 deg. C. compared with curing at 182 deg. C.; prolonging the period of curing at the lower temperature, however, resulted in increased strength, although after curing for four days this was still less than that of specimens cured for one day at 182 deg. C.

When bars were subjected to a bending test, the modulus of rupture of those containing silica and steam cured was 2590 lb. per square inch compared with 1300 lb. per square inch in the case of neat Portland cement moist-cured at 46 deg. C.; the bars were tested two months after they were made.

The authors give the following notes on the results of the tests.

FORMATION OF DICALCIUM SILICATE ALPHA-HYDRATE.—For mixtures with cement-silica ratios from 1·44 to 3·04 and cured at 182 deg. C. for twenty-four hours, dicalcium silicate alpha-hydrate appeared. This hydrate could not be produced when a mixture with a cement-silica ratio of 1·44 was cured at 126 deg. C. for twenty-four hours, but a small amount of fibrous tobermorite was present. It appears that the alpha-hydrate is formed only at relatively high temperatures in this range of composition. By X-ray diffraction, Kalousek and others[1] found

this hydrate to be present at 175 deg. C. in mixtures of $Ca(OH)_2$ and quartz with cement-silica ratios of 1·8 to 2·4. Heller and Taylor[2] found the alpha-hydrate, together with $Ca(OH)_2$, to be the product of hydrolysis of pure tricalcium silicate at temperatures between 100 and 200 deg. C. They postulate that the alpha-hydrate is stable over this temperature range in the presence of excess $Ca(OH)_2$, but that it can be no more than a transition product when formed from starting materials of its own cement-silica ratio or lower.

Using mixtures of Portland cement and ground quartz, Kalousek and Adams[3] found that an addition of 9 per cent. of quartz was sufficient to react with all the free lime at 175 deg. C. The maximum amount of alpha-hydrate was also produced with this addition. Menzel[4] found the strength to be a minimum at about this composition. Butt and others[5] also found that in hydrothermally-treated mixtures of quartz and tricalcium silicate the maximum amount of alpha-hydrate coincides with a minimum of mechanical strength. The results of the investigation now reported substantially confirm these findings.

FORMATION OF TRANSITIONAL HYDRATES.—Kalousek[6] has stated that with 0·8 : 1 cement-silica mixtures of $Ca(OH)_2$ and ground quartz, cured at 175 deg. C., the lime first reacts with the siliceous material to form the lime-rich phases which may include the C_2S alpha-hydrate. Further hydrothermal treatment then results in a reaction between the residual quartz and the lime-rich phases to form the tobermorite-type hydrates. He is of the opinion that this transition is gradual and involves intermediate transitions through a number of hydrates of progressively lower cement-silica ratios. The cement-silica ratios of these intermediate hydrates range from 1·33 to 0·8. Their X-ray diffraction patterns were nearly the same, and all contained a large diffuse peak at 3·04A. He found them to be fibrous in nature when viewed under the electron microscope. If the reaction is then carried to a completion under these hydrothermal conditions, the resulting product is the platy or stable phase of tobermorite. This material, given the formula $C_4S_5H_5$, was found by Kalousek to be in the form of flat or rolled plates under the electron microscope.

In the investigation now reported, the existence of any lime-rich phases as transitional hydrates in the 0·9 or 0·77 cement-silica mixtures could not be determined because there were no autoclaving periods shorter than sixteen hours. With cement-silica ratios higher than about 2, and at the same temperature of 182 deg. C., the C_2S alpha-hydrate appears to be the stable phase.

The role of the fibrous tobermorite at the higher cement-silica ratios and at 182 deg. C. is not clear. In all cases where the alpha-hydrate exists the fibrous phase is also present. Under these conditions the maximum amount of the fibrous phase is produced with a cement-silica ratio of 3·04 (neat Portland cement). With the addition of 10 per cent. of quartz the 3·04A fibrous tobermorite peak diminishes considerably. With the addition of 20 per cent. of quartz the fibrous phase increases slightly and the platy phase appears. The fibrous phase was found in all mixtures which contained the platy or strength-giving phase of

tobermorite. With further additions of quartz the amount of fibrous phase seemed to decrease slightly and the platy phase increased. The fibrous phase did not begin to diminish appreciably until the addition of 50 per cent. quartz (cement-silica ratio 0·56).

At temperatures below about 126 deg. C., and at all cement-silica ratios, the fibrous phase ratio is the only calcium silicate hydrate existing and is always accompanied by some free lime. The only exception might be the 0·9 mixture which was moist-cured for four days at 46 deg. C. In this case there was some indication of the presence of okenite, CS_2H_2, along with the fibrous phase and free lime. This same mixture, when steam-cured at 126 deg. C. for twenty-four hours developed more of the fibrous phase and less free lime. The neat Portland cement moist-cured at 46 deg. C. contained only the fibrous phase with a large amount of free lime. No distinct correlation was found between the amount of the fibrous phase present and the mechanical strength of the various cements tested.

FORMATION OF PLATY TOBERMORITE.—The results show clearly that, if cured under the proper conditions of time and temperature, a substance previously identified as the platy phase of the calcium silica hydrate (Tobermorite) is the principal bonding material in an autoclaved concrete product containing Portland cement and ground quartz. This platy tobermorite could be produced by using mixtures of cement and ground quartz ranging in cement-silica ratios from 1·44 to 0·56, and possibly lower, when cured hydrothermally at 182 deg. C. for twenty-four hours. The maximum amount of platy tobermorite was produced in the mixture containing 12·7-micron quartz with a starting cement-silica ratio of 0·9, and the resulting cement mixture exhibited the greatest strength. Menzel[4] found that additions of quartz between 30 and 35 per cent. produced the strongest cement mixtures. Butt[5] showed that in hydrothermally-treated mixtures of quartz and beta-dicalcium silicate a maximum amount of "0·9 hydrate" occurs with the addition of 40 to 50 per cent. of quartz, coinciding also with a maximum mechanical strength.

The minimum autoclave temperature needed here to produce the platy tobermorite is between 126 deg. C. and 159 deg. C. in the case of the 0·9 mixture; a temperature of 182 deg. C. resulted in the formation of the greatest amount of the platy tobermorite. At 182 deg. C. curing periods of 16, 24, and 48 hours produced the platy phase in nearly the same amounts. Kalousek found that, when using a 0·8 cement-silica mixture of $Ca(OH)_2$ and quartz, formation of the platy tobermorite was nearly complete in eight hours at 175 deg. C. Results here also show that the composition and hydrothermal conditions of time and temperature needed to produce the platy tobermorite vary with the type and particle size of the siliceous aggregate used.

The most outstanding increase in strength of cement containing the platy phase of tobermorite was shown by the modulus of rupture tests on bars made with the 0·9 cement-silica mixture of 12·7 micron quartz and Portland cement which was steam-cured for twenty-four hours at 182 deg. C. Bars containing

the platy tobermorite phase had exactly double the strength of the moist-cured neat Portland cement bars. Since under transverse loading the initial fracture of the cement bar would occur at the surface in tension, these results indicate that the sheet-like platy tobermorite crystals are much more effective in increasing the tensile or bonding strength of the resulting cement. This increase in tensile strength may not have been completely realised with the metal test units in which the cement was subjected to a shearing type of stress.

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The Cement Industry in Dominica.

The Department of Industry and Commerce of the Dominican Republic states that the production of cement in the year 1957 was 280,402 tons, all of which was produced by Fabrica Dominicana de Cemento. Exports amounted to 70,000 tons, principally to the United States. The largest works is at Ciudad Trujillo, and has an annual capacity of over 300,000 tons. Three kilns are in use, one of which is 227 ft. long by 9 ft. 6 in. diameter, another 247 ft. long by 9 ft. diameter, and another 360 ft. long by 11 ft. 3 in. diameter.

Proposed Cement Works in Ceylon.

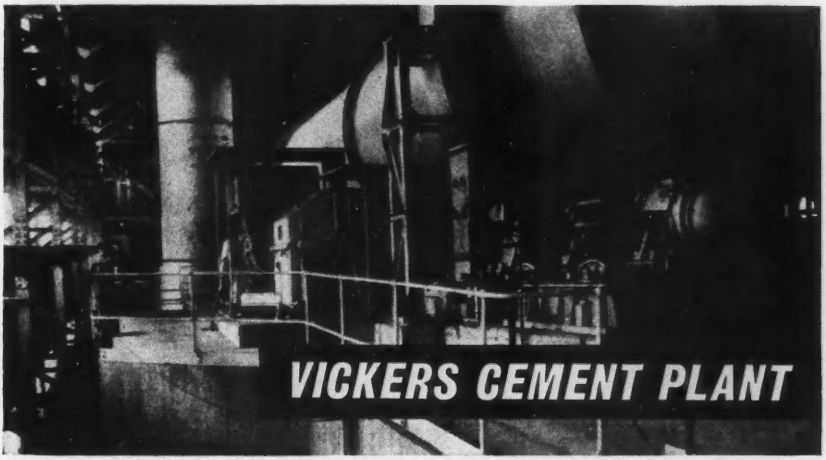
The Government of Ceylon has allocated Rs. 13,000,000 for the erection of a cement works at Puttalam. It is estimated that the total cost will be Rs. 38,000,000. The capacity of the works is to be 125,000 tons a year, and it is expected that production will start in 1962.

A Proposed Cement Factory in East Pakistan.

The Government of Pakistan has received an offer from Japan for the construction of a cement factory at St. Martin's Island, East Pakistan. The basic material used would be coral.

Cement Production in Mexico.

The production of cement in Mexico in the year 1957 was 2,519,000 tons, compared with 2,277,000 tons in 1956.



The kiln showing driving gear and supporting rollers.

The two 1,200 h.p. clinker mills.

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Injuries due to Falling.

SAFETY Pamphlet No. 3 issued by the Cement Makers' Federation deals with injuries due to men falling in and around cement works. Accidents of this type have in the past few years been responsible for from 20 to 26 per cent. of all accidents in the cement industry causing loss of working time. Last year there were 72 such accidents, of which 33 were falls on the level, 29 falls from a height, and 10 falls into holes. The Accident Prevention Advisory Committee of the Federation points out that nearly all these accidents could have been prevented by ordinary forethought, tidiness, or inexpensive permanent or temporary fencing. This is clearly shown by some of the causes mentioned. These include the following examples.

FALLS ON THE LEVEL.—(1) A man was using a two-wheeled barrow to remove burst bags; the barrow tipped sideways owing to the uneven floor, and the man's hand was trapped between the barrow-handle and a wire-mesh grid. (2) A man wheeling a barrow down an untreated ramp slipped and fell, twisting his leg. (3) A man slipped on a grease-patch on the steps of a gantry, fell off the steps, and injured his groin. (4) A man fixing a portable lead stepped back and fell over two old pulleys, fracturing a rib. (5) A man walking along a well-lit passage turned a corner and was suddenly in semi-darkness; he fell down two steps and fractured a wrist. (6) A man stepped from a locomotive on to loose clinker which caused him to fall and injure his elbow. (7) Whilst helping to move a pile of steel rods a man stood on one of them; the rod rolled and he fell, severely injuring his ribs. (8) In walking down a ramp a man tripped over a lamp-lead and badly injured his arm. (9) A pipe was temporarily laid across the floor between two boilers; a man tripped over it and strained his back. (10) A man slipped on a wet board and fell, causing injury to his elbow; he was wearing boots which were totally unsuitable for the work on which he was engaged. (11) A man took a short cut down a bank and tripped at the bottom, spraining his knee. (12) A man carrying a steel plate across a yard slipped on the icy surface; the plate fell on to his leg and fractured it.

FALLS FROM A HEIGHT.—(1) A man climbed down a short ladder from which the last but one rung was missing and the last rung was broken; he fell and injured his ankle. (2) Part of a walkway on a gantry had been removed and not securely replaced; due to this defect a man fell about 10 ft. and was seriously injured. (3) A man slipped off a drum on which he was standing in order to reach his work, and severely injured his back. (4) In order to clean a gutter a man stepped on to a fragile roof and fell through it. (5) A bolt securing a handrail stanchion had worked out; a man stumbled against the rail which gave way and swung outwards. (6) A steel plate between a lorry and a loading bay slipped while a man was wheeling cement bags over it; he fell and was injured. (7) A man standing on the mudguard of a lorry in order to clean the windscreen stepped off the mudguard and fell, spraining his hand.

FALLS INTO HOLES.—(1) A man walked over a heap of rubble partly surround-

ing an unguarded hole; he slipped into the hole, fracturing his ribs. (2) A cover for a screw-conveyor was removed and not replaced; a man fell into the conveyor, receiving injuries which resulted in the loss of a foot. (3) A fitter removed the cover-plate of a screw-conveyor and covered the hole with a sack; another man stepped on the sack and into the screw, which had been inadvertently started, and suffered injuries resulting in the loss of a leg.

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BINDING cases for annual volumes of "Cement & Lime Manufacture" can be supplied in cloth-covered boards lettered in gold on the spine with the title, volume number, and year of publication. Copies for binding should be sent post paid to Concrete Publications Ltd., 14 Dartmouth Street, London, S.W.1. When possible, missing numbers will be supplied at the published price to make up incomplete sets, but as many of the numbers published during the past few years are not available it is advisable to ask the publishers whether thay have the numbers required before sending incomplete sets. The cost of cloth-covered lettered cases is 6*s.* for each volume. The cost of supplying a case and binding a volume is 10*s.* 10*d.* including packing and carriage.

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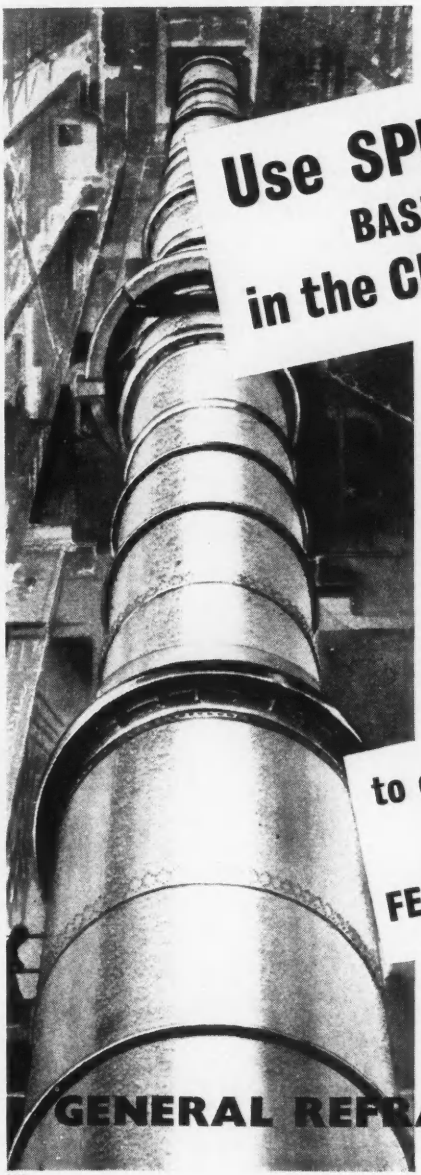

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